# *SR 84 Miner Slough Bridge Number 23-0035 Replacement Project*

## Analysis of Potential Underwater Construction Noise Assessment

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## Executive Summary

This report summarizes the results of a noise assessment of possible construction activities related to the replacement of the Miner Slough Bridge on State Route 84 (SR 84) in Solano County about 30 miles southwest of Sacramento, California. The purpose of this assessment is to predict construction noise levels to be used by California Department of Transportation (Caltrans) staff to address concerns and questions raised about the potential project effects on sensitive habitat and aquatic species. The assessment focuses on predicting underwater noise levels from pile driving activities. There are two components to the analysis; first the construction of the new bridge; secondly the construction of the temporary trestles, falsework structure, and coffer dams. Results of this assessment are summarized as follows:

- New bridge: Driving of small diameter steel shell piles, 2-foot in diameter, at Pier 3 in a coffer dam could generate underwater maximum peak sound pressure levels of about 200 decibels (dB) at 33 feet from the pile. Sound levels could be much lower in very shallow (i.e., less than 3 feet deep) portions of the slough. Pile driving activities at Pier 4 will be conducted near the slough and would generate groundborne vibration that could produce underwater noise. Pile driving activities conducted on land near water bodies have been found to transmit low frequency sound into the water. The mechanisms for transmitting this sound into the water are complex and difficult, if not impossible, to predict. It is anticipated that substantial sounds transmitted into the water from pile driving would only occur where the water is relatively deep (3 feet or greater). he maximum peak sound pressure levels of over 200 dB could be expected in the water. Driving of large diameter steel shell piles, 72-inch in diameter, at Pier 2 could generate maximum peak levels in excess of 214 dB at 10m. Vibratory installation of sheet piles for the coffer dam at Pier 3 are expected to generate root mean square (RMS) noise levels of 160 dB at 10m. The piles for the abutments are well outside the wetted channel and the levels generated from that pile driving are expected to be below the National Maine Fisheries Service (NMFS) interim thresholds.
- Temporary construction trestle: The new bridge construction will require the construction of a temporary work trestle. The driving of small steel shell piles between 15- and 36-inches could generate underwater maximum peak sound pressure levels between 200 and 210 dB at 33 feet from the pile. It is anticipated that substantial sounds transmitted into the water from pile driving would only occur in the deeper portions of the slough where the water is relatively deep (6 feet or greater). Driving of small steel shell piles on land near the slough is likely to result in peak sound pressure levels of less than 200 dB.

## Introduction

Caltrans is planning the replacement of the Miner Slough Bridge No. 23-0035 on SR 84 in Solano County about 30 miles southwest of Sacramento, California at PM 12.1/12.2. The existing bridge is a swing bridge with nonstandard geometry and very low annual average daily traffic (AADT) (336 in 2011) connecting Ryer Island in the Sacramento River delta to the mainland over Miner Slough. One build alternative is proposed, which is a bridge replacement alternative. The proposed replacement project involves construction of a new bridge, building a temporary work trestle, and demolition of the existing bridge. The portions of the project that will impact the noise in the river include impact driving pile installation for permanent steel shell piles at bridge Pier 4 and impact driven pile installation for small diameter steel shell piles for both abutments and Piers 2 and 3, as well as installation of temporary piles for false work, temporary piles for a temporary pier, temporary piles for trestles, and sheet piles (to be vibrated in) for coffer dams within the river channel.

This study is an assessment of potential underwater noise levels generated by planned construction activities involved with replacement of the SR 84 Miner Slough Bridge. The study was requested in order to aid Caltrans biologists in assessing noise impacts to fisheries and is focused on providing the following information:

- Range of underwater noise levels from pile driving conducted within and near the Miner Slough.

Our assessment is based on information provided by Caltrans staff consisting of a location map, draft layout sheets, estimated pile driving data, a review of potential construction activities to be conducted at the site, a review of related studies, the modeling, and a semi-quantitative analysis of underwater noise levels. This study assesses the underwater noise levels associated with potential pile driving activities as experienced at the identified noise sensitive areas noted above. The study does not address environmental impacts associated with the project.

## Underwater Sounds from Pile Driving

### Fundamentals of Underwater Noise

Sound is typically described by the *pitch* and *loudness*. *Pitch* is the height or depth of a tone or sound, depending on the relative rapidity (*frequency*) of the vibrations by which it is produced. *Loudness* is intensity of sound waves combined with the reception characteristics of the auditory system. Intensity may be compared with the height of an ocean wave in that it is a measure of the amplitude of the sound wave.

In addition to the concepts of pitch and loudness, there are several noise measurement scales which are used to describe sound. A *decibel (dB)* is a unit of measurement describing the amplitude of sound; a decibel is equal to 20 times the logarithm to the base 10 of the ratio of the pressure of the sound measured to the reference pressure. For underwater sounds, a reference pressure of 1 *micro pascal* (*μPa*) is commonly used to describe sounds in terms of decibels.

Therefore, 0 dB on the decibel scale would be a measure of sound pressure of 1 µPa. Sound levels in decibels are calculated on a logarithmic basis. An increase of 10 decibels represents a ten-fold increase in acoustic energy, while 20 decibels is 100 times more intense, 30 decibels is 1,000 times more intense, etc.

When a pile driving hammer strikes a pile a pulse is created that propagates through the pile and radiates sound into the water, the ground substrate, and the air. Sound pressure pulse as a function of time is referred to as the waveform. In terms of acoustics, these sounds are described by the peak pressure, the *root mean square pressure* (*RMS*), and the *sound exposure level* (*SEL*). The peak pressure is the highest absolute value of the measured waveform, and can be a negative or positive pressure peak. For pile driving pulses, RMS level is determined by analyzing the waveform and computing the average of the squared pressures over the time that comprise that portion of the waveform containing the vast majority of the sound energy.[1] The pulse RMS has been approximated in the field for pile driving sounds by measuring the signal with a precision sound level meter set to the "impulse" RMS setting and is typically used to assess impacts to marine mammals. Another measure of the pressure waveform that can be used to describe the pulse is the sound energy itself. The total sound energy in the pulse is referred to in many ways, such as the "total energy flux".[2] The "total energy flux" is equivalent to the un-weighted SEL for a plane wave propagating in a free field, a common unit of sound energy used in airborne acoustics to describe short-duration events referred to as dB re 1µPa2-sec. Peak pressures and RMS sound pressure levels are expressed in dB re:1µPa. The total sound energy in an impulse accumulates over the duration of that pulse. Figure 1 illustrates the descriptors used to describe the acoustical characteristics of an underwater pile driving pulse. Table 1 includes the definitions of terms commonly used to describe underwater sounds.

The variation of instantaneous pressure over the duration of a sound event is referred to as the waveform. Studying the waveforms can provide an indication of rise time; however, rise time differences are not clearly apparent for pile driving sounds due to the numerous rapid fluctuations that are characteristic to this type of impulse. A plot showing the accumulation of sound energy over the duration of the pulse (or at least the portion where much of the energy accumulates) illustrates the differences in source strength and rise time. An example of the characteristics of a typical pile driving pulse is shown in Figure 1.

[1] Richardson, Greene, Malone & Thomson, *Marine Mammals and Noise*, Academic Press, 1995 and Greene, personal communication.
[2] Finerran, et. al., *Temporary Shift in Masked Hearing Thresholds in Odontocetes after Exposure to Single Underwater Impulses from a Seismic Watergun*, Journal of the Acoustical Society of America, June 2002.

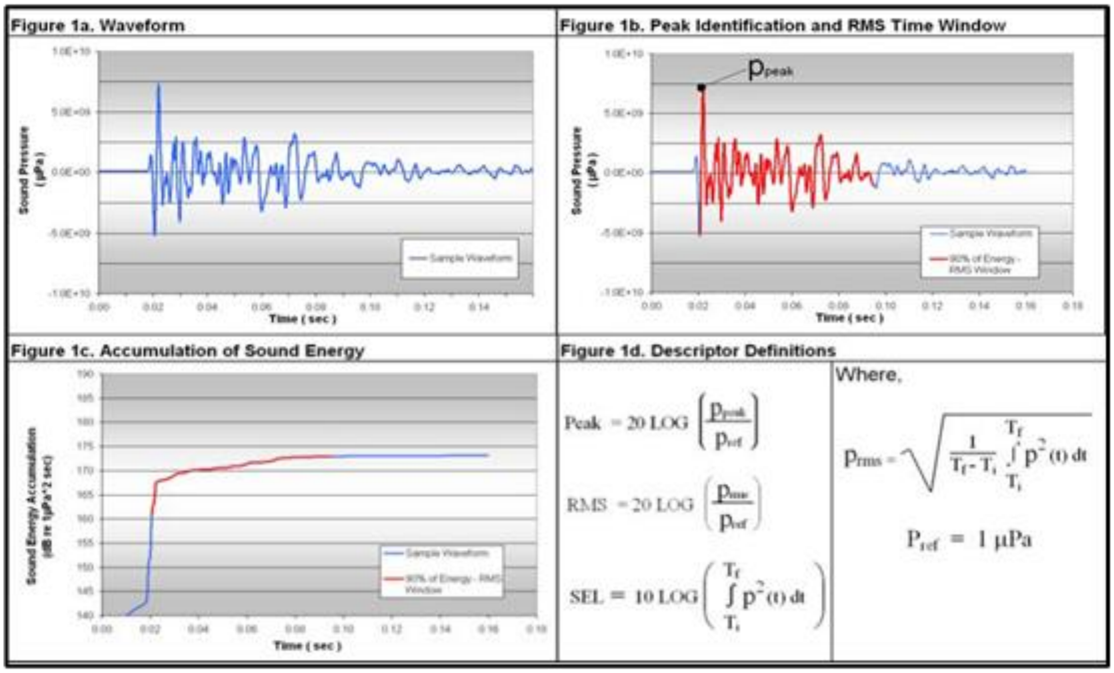


**Figure 1 - Characteristics of a Pile Driving Pulse**

**Table 1 - Definitions of Underwater Acoustical Terms**

| Term | Definition |
|---|---|
| Decibel, dB | A unit describing, the amplitude of sound, equal to 20 times the logarithm to the base 10 of the ratio of the pressure of the sound measured to the reference pressure. The reference pressure for air is 20 micro pascals (µPa) and 1 µPa for underwater. |
| Equivalent Noise Level, $L_{eq}$ | The average noise level during the measurement period. |
| $L_{01}$, $L_{10}$, $L_{50}$, $L_{90}$ | The sound levels that are exceeded 1%, 10%, 50%, and 90% of the time during the measurement period. |
| Peak Sound Pressure, unweighted (dB) | Peak sound pressure level based on the largest absolute value of the instantaneous sound pressure. This pressure is expressed in this report as a decibel (referenced to a pressure of 1 µPa) but can also be expressed in units of pressure, such as µPa or PSI. |
| RMS Sound Pressure Level, (NMFS Criterion) | The average of the squared pressures over the time that comprise that portion of the waveform containing 90 percent of the sound energy for one pile driving impulse.[3] |
| Sound Exposure Level (SEL), dB re 1 $\mu Pa^2$ sec | Proportionally equivalent to the time integral of the pressure squared and is described in this report in terms of dB re 1 $\mu Pa^2$ sec over the duration of the impulse. Similar to the unweighted Sound Exposure Level (SEL) standardized in airborne acoustics to study noise from single events. |
| Cumulative SEL | Measure of the total energy received through a pile-driving event (here defined as pile driving over one day or maximum of 3 piles) that occurs with a day). |
| Waveforms, µPa over time | A graphical plot illustrating the time history of positive and negative sound pressure of individual pile strikes shown as a plot of µPa over time (i.e., seconds). |
| Frequency Spectra, dB over frequency range | A graphical plot illustrating the distribution of sound pressure vs. frequency for a waveform, dimension in RMS pressure and defined frequency bandwidth. |

SEL is an acoustic metric that provides an indication of the amount of acoustical energy contained in a sound event. For pile driving, the typical event can be one pile driving pulse or many pulses such as pile driving for one pile or for one day of driving multiple piles. Typically, SEL is measured for a single strike and a cumulative condition. The cumulative SEL associated with the driving of a pile can be estimated using the single strike SEL value and the number of pile strikes through the following equation:

$$SEL_{CUMULATIVE} = SEL_{SINGLE\ STRIKE} + 10 \log (\#\ of\ pile\ strikes)$$

For example, if a single strike SEL for a pile is 165 dB and it takes 1,000 strikes to drive the pile, the cumulative SEL is 195 dBA (165 dB + 30 dB = 195 dB), where $10 * \mathrm{Log}_{10}(1000) = 30$.

[3] The underwater sound measurement results obtained during the Pile Installation Demonstration Project indicated that most pile driving impulses occurred over a 50 to 100 millisecond (msec) period. Most of the energy was contained in the first 30 to 50 msec. Analysis of that underwater acoustic data for various pile strikes at various distances demonstrated that the acoustic signal measured using the standard “impulse exponential-time-weighting” (35-msec rise time) correlated to the RMS (impulse) level measured over the duration of the impulse.

Underwater Sound Thresholds

Underwater sound affects to fish are discussed below. In this report, peak pressures and RMS sound pressure levels are expressed in decibels re 1 µPa. Sound exposure levels are expressed as dB re 1µPa$^2$-sec.

Fish

A Fisheries Hydroacoustic Workgroup (FHWG) consisting of transportation officials, resources agencies, the marine construction industry (including Ports), and experts was formed in 2003 to address the underwater sound issues associated with marine construction. The first order of business was to document all that was clearly known about the effects of sound on fish, which was reported in "The Effects of Sound on Fish".[4] This report provided recommended preliminary guidance to protect fish. A graph showing the relationship between the SEL from a single pile strike and injurious effects to fish based on size (i.e., mass) was presented. Fish with a mass of about 0.03 grams were expected to have no injury for a received SEL of a pile strike below 194 dB and suffer 50% mortality at about 197 dB. The report also described possible effects to the auditory system (i.e., auditory tissue damage and hearing loss) based on a received dose of sound. The recommendations were frequency dependent, based on the hearing thresholds of fish, or most sensitive auditory bandwidths. For salmonids, hearing effects would be expected at or near the thresholds for injury based on the single strike SEL. A further investigation into the effects of pile driving sounds on fish was also recommended.

Caltrans commissioned a subsequent report to provide additional explanation of, and a practical means to apply, injury criteria recommended in The Effects of Sound on Fish. This report is entitled "Interim Criteria for Injury of Fish Exposed to Pile Driving Operations: A White Paper".[5] The White Paper recommended a dual criterion for evaluating the potential for injury to fish from pile driving operations. The dual approach considered that a single pile strike with high enough amplitude, as measured by zero to peak (either negative or positive pressure) could cause injury. A peak pressure threshold for a single strike was recommended at 208 dB. In 2007, Carlson et al provided an update to the White Paper in a memo titled "Update on Recommendation for Revised Interim Sound Exposure Criteria for Fish during Pile Driving Activities".[6] In this memo, they propose criteria for each of the three different effects on fish; 1) hearing loss due to temporary threshold shift, 2) damage to auditory tissues, and 3) damage to non-auditory tissues. These criteria vary due to the mass of the fish and if the fish is a hearing specialist or hearing generalist. In preparing this update, Dr. Mardi Hastings summarized information from some current studies in a report titled "Calculation of SEL for Govoni et al. (2003, 2007) and Popper et al. (2007) Studies".

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[4] Hastings, M and A. Popper. 2005. The Effects of Sound on Fish. Prepared for the California Department of Transportation. January 28 (revised August 23).

[5] Popper, A., Carlson, T., Hawkins, A., Southall, B. and Gentry, R. 2006. Interim Criteria for Injury of Fish Exposed to Pile Driving Operations: A White Paper. May 14.

[6] Carlson, T, Hastings, M and Poper, A. 2007. Memo to Suzanne Theiss, California Department of Transportation, Subject: Update on Recommendations for Revised Interim Sound Exposure Criteria for Fish during Pile Driving Activities. December 21.

On June 12, 2008, NMFS; U.S. Fish and Wildlife Service; California, Oregon, and Washington Departments of Transportation; California Department of Fish and Wildlife; and the U.S. Federal Highway Administration generally agreed in principal to interim criteria to protect fish from pile driving activities, as shown in Table 2. Note that the peak pressure criteria of 206 dB was adopted (rather than 208 dB), as well as accumulated SEL criteria for fish smaller than 2 grams. NMFS interpretation of the interim criteria is described by Woodbury and Stadler (2009).[7]

**Table 2 - Adopted Impact Pile Driving Acoustic Criteria for Fish**

| Interim Criteria for Injury | Agreement in Principle |
|---|---|
| Peak | 206 dB for all size of fish |
| Cumulative SEL | 187 dB for fish size of two grams or greater.<br>183 dB for fish size of less than two grams. |
| Behavior effects threshold 150 dB RMS | |

The primary difference between the adopted criteria and previous recommendations is that the single strike SEL was replaced with a cumulative SEL over a day of pile driving. NMFS does not consider sound that produces an SEL per strike of less than 150 dB to accumulate and cause injury. The adopted criteria listed in Table 2 are for pulse-type sounds (e.g., pile driving) and does not address sound from vibratory driving of piles; there are no acoustic thresholds that apply to the lower amplitude noise produced by vibratory pile driving. In fact, the acoustic thresholds developed for fish only apply to impact pile driving.

The Bureau of Ocean Energy Management, (BOEM -formerly Minerals Management Service), Caltrans, and National Cooperation of Highway Research Programs (NCHRP 25–28)/Transportation Research Board (TRB) have funded studies to identify the onset of injury to fish from impact pile driving. One of the goals of these studies was to provide quantitative data to define the levels of impulsive sound that could result in the onset of barotrauma injury to fish.[8] Laboratory simulation of pulse-type pile driving sounds enabled careful study of the barotrauma effects to Chinook salmon. The neutrally buoyant juvenile fish were exposed to impulsive sounds and subsequently evaluated for barotrauma injuries. Significant barotrauma injuries were not observed in fish exposed to 960 pulses at 180 dB SEL per pulse or 1,920 pulses at 177 dB per pulse. In both exposures, the resulting accumulated SEL was 210 dB SEL. Results of these studies are under review. At this time, the criteria in Table 2 are used by NMFS to judge impacts to fish. Potential behavior impacts that might occur above 150 dB RMS are not used to restrict pile driving.

[7] Stadler, J. and Woodbury, D. 2009. Assessing the effects to fishes from pile driving: Application of new hydroacoustic criteria. Proceedings of inter-noise 2009, Ottawa, Canada. August 23-26.
[8] Halvorsen MB, Casper BM, Woodley CM, Carlson TJ, Popper AN (2012) Threshold for Onset of Injury in Chinook Salmon from Exposure to Impulsive Pile Driving Sounds. PLoS ONE 7(6): e38968. oi:10.1371/journal.pone.0038968

## Underwater Noise Levels from Construction

The primary type of activity that has the potential to elevate underwater noise levels is the installation of piles. There are two (2) basic methods that are proposed to install piles including vibrating and impact driving. For this project the piles are planned to be installed with using either a diesel impact hammer or a vibratory hammer.

Pile Driving

There are basically two different and distinct structures that will be constructed for the bridge replacement project, a temporary work trestle and the new structure. For the new structure, the water pile installations will consist of sheet piles for a coffer dam, small diameter steel shell piles driven within the coffer dam, and two 72-inch steel shell piles that will be impact driven for Pier 4. Approximately 88 sheet piles will be vibrated, 25 24-inch steel pipe piles will be vibrated in then driven to final tip elevation with an impact hammer, and the 72-inch steel shell piles will be impact driven in. The remainder of piles for the new bridge structure will be installed outside the wetted channel. These piles consist of 24-inch piles for both abutments and the 72-inch steel shell pile for Pier 2.

The temporary trestle structure will be designed by the contractor at a later date. However, it is estimated that the trestle will have a width of 35 to 40 feet with a superstructure of timber decking, steel stringers, a prefab steel bent caps, and a safety rail. The bents will be spaced approximately 25 to 40 feet apart. There should be between 24 to 32 bents. It is anticipated that 15- to 36-inch diameter steel shell piles will be driven or vibrated and will be spaced 5-feet to 10-feet apart. The number of piles may range from 150 to 400. Each pile will be approximately 50 to 75-feet in length. Because there are no plans for this temporary trestle, it was assumed to use the worst case of the estimated design for the assessment. This would assume that the piles are impact driven and the bent spacing would be 25 feet and using 36-inch steel shell piles spaced along the stringer at 5-foot intervals. This would equate too approximately 12 bents with 9 piles per bent or a total of 108 36-inch steel shell piles for the temporary trestle. Approximately 72 of the piles will be in the wetted channel and the remainder will be driven on land at both sides of the slough. The water depth where the temporary trestle pile will be driven ranges from two (2) feet deep to ten (10) feet deep.

Pile driving in the water causes sound energy to radiate directly into the water by vibrating the pile between the surface of the water and the riverbed, and indirectly as a result of groundborne vibration at the riverbed. Airborne sound does not make a substantial contribution to underwater sound levels because of the attenuation at the air/water interface. Pile driving near the river would generate low-frequency groundborne vibration that can cause localized sound pressures in the water that are radiated from the streambed. A minimum water depth is required to allow sound to propagate. For pile driving sounds, the minimum depth is 3 to 6 feet. Low frequency vibration caused by pile driving would propagate through the ground only and couple to the water at the sloughbed.

Due to the complexity of the environment (shallow and slow moving water), it is not possible to accurately predict underwater sound pressures from pile driving activities that may occur near the river. The likelihood of pile driving causing high widespread sound levels is low, given the shallowness of the water and types and sizes of piles under consideration for this project. The water surface is a pressure release zone. Underwater sound measurements have shown that levels are considerably lower in the top 3 feet. Levels are typically highest in the deepest portions of the water column. In deeper water (i.e., 30-feet or deeper), levels are fairly uniform with depth except in the top six (6) feet where they decrease with decreasing depth. In portions of the slough that are 6 feet or less in depth, low sound pressure levels are expected.

**New Miner Slough Bridge:**

The underwater noise levels used in this report were derived from the Caltrans Guidance Manual and the 2012 hydroacoustic Compendium[9], these documents can be found on the Caltrans web page at: http://www.dot.ca.gov/hq/env/bio/fisheries_bioacoustics.htm and are shown in Attachment A. The numbers were then adjusted to reflect the onsite conditions. The NMFS underwater calculator was used to calculate the distances to the various thresholds shown in Table 2.

The project proposes to build a new swing bridge about 100 feet west of existing alignment. The new bridge will have standard features with a 12 foot travel way and 8 foot shoulder in each direction. The vertical clearance of proposed structure will be standard 15 feet. The project would require construction of a temporary trestle bridge, a control-house structure on the levee, and a viaduct on the levee to accommodate Maintenance parking for the control house. The project will construct three steel-reinforced cast concrete piers to support the bridge: one central pivot pier (Pier 3) and independent piers (2 and 4) which support the approach spans, and also support the swing span when it is not in operation. A cap will be constructed of steel-reinforced cast concrete over each foundation, over which the pier itself will be constructed. Each pier will be built on a Cast in Steel Shell (CISS) foundations.

For Pier 3, a 44 by 44-foot cofferdam will be constructed to facilitate the pile driving and the construction of caps and the pier. The cofferdam is constructed by driving 24-inch sheet piles 30 feet into the streambed using vibratory hammers. The piles will be tall enough so that the tops reach 5 feet above the surface of the water and placed adjacent to each other to form a void from which water can be evacuated. The cofferdam is then dewatered and the area inside the base of the cofferdam excavated to about 2 feet below the footing elevation. A 2-foot deep seal course of poured concrete is placed at the base of the cofferdam to aid in dewatering and prevents construction material from escaping through the base of the cofferdam.

For Piers 2 and 4, 72-inch CISS piles will be driven without cofferdams into the streambed using impact hammers, and the pile shells drilled out, leaving a plug of native material at the bottom.

[9] Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish, California Department of Transportation, February 2009 and the 2012 Hydroacoustic Compendium

Further extensions without trestles, attached to the trestle-supported extensions of the temporary bridge, will be used to guide the piles into their correct locations, and to capture material brought out of the shells by the drilling.

On the levees, at the ends of each approach span a row of 28, 24-inch piles with a 65.5-foot by 8-foot wide concrete cap will be constructed. The area will be excavated to a depth of 5-feet for 60-feet to construct trench 5-feet wide. 70-foot long CISS piles will be driven into the trench, drilled out, and filled with rebar and concrete. The 65.5 foot long, by 8 foot wide, and 5 foot deep cap will be constructed over the tops of the piles to support the approach span. Table 3 shows the size and number of piles for each pier and the abutments.

**Table 3 – Number and Types of Piles for Foundation**

| | ***Pier 3*** | ***Piers 2 and 4*** | ***Abutments 1 and 5*** |
|---|---|---|---|
| Number of piles | 25 | 4 | 56 |
| Depth of piles | 100-feet | 100-feet | 70-feet |
| Diameter of pile | 24-inch | 72-inch | 24-inch |

There are four (4) large diameter steel shell piles that will be either directly installed in the river or near the water's edge and these piles will be installed using both vibratory and impact driving. The remainder of the piles installed at Pier 3 and both abutments will be either installed on land away from the water or in a de-watered coffer dam.

<u>Cofferdam Sheet Metal Piles:</u>

Typically sheet piles for cofferdams are driven using a vibratory hammer. There is not much information on the noise levels from driving sheet piles with a vibratory hammer. Measurements were made at Ten Mile River north of Fort Bragg, California and at the East Fork of the Salmon River Bridge near Challis, Idaho when a vibratory hammer was used to drive sheet piles. At Challis, some of the same piles were later driven to the final tip elevation using a hydraulic impact hammer. The peak sound pressure generated from the use of the vibratory hammer was 170 dB at 33 feet and when a hydraulic impact hammer was used the peak sound pressure was 179 dB. At this project the sound pressure generated by the vibratory hammer was ~9 dB lower than those generated by the impact hammer.

Pier 3 will have a coffer dam constructed using sheet piles prior to installing the 24-inch steel shell piles for the foundation of the center-pivot foundation. The sheet piles driven for Pier 3 will have a fish harassment of 128 feet. Table 4 shows the levels and distance to all appropriate NMFS criteria.

**Table 4 – Distances to various NMFS Criteria vibrating in Steel Sheet piles**

| ***Location*** | ***Distance to water*** | ***Peak*** | ***RMS*** | ***Distance to 150 dB RMS Criteria (feet)*** |
|---|---|---|---|---|
| Pier 3 | Center of Sough | 175 | 160 | 128 |

Foundation Piles:

All the piles will be installed in the same manner, vibrated in part of the way and then driven to final tip elevation using an impact hammer. Table 5 shows the levels for the attenuated and unattenuated impact pile driving. Piles driven on land such as the piles at the abutments and Pier 4 are driven on land and as such there was no attenuation used. Levels used were derived from the Caltrans Guidance Manual and the 2012 hydroacoustic Compendium[10] and are shown in Attachment A.

**Table 5 – Near-Source Levels for Unattenuated and Attenuated Impact Pile Driving [A]**

| Pile Type | Peak | | RMS | | Single Strike SEL | |
|---|---|---|---|---|---|---|
| | Unattenuated | Attenuated | Unattenuated | Attenuated | Unattenuated | Attenuated |
| Abutment 1 – 2-foot Steel Shell Piles on Land | 179 | N/A | 159 | N/A | 150 | N/A |
| Pier 2 - 6-foot Steel Shell Piles in Water | 214 | 204 | 199 | 189 | 189 | 179 |
| Pier 3 - 2-foot Steel Shell Piles in Coffer Dam | 200 | 190 | 185 | 175 | 172 | 162 |
| Pier 4 - 6-foot Steel Shell Piles On Land | 204 | N/A | 185 | N/A | 175 | N/A |
| Abutment 5 – 2-foot Steel Shell Piles on Land | 172 | N/A | 185 | N/A | 146 | N/A |

[A] Near-source is considered 33 feet from pile.

72-inch Steel Shell Piles:

Piers 2 and 4 each have two 72-inch steel shell piles that will be impact driven. Pier 2 is on the south side of Miner Slough in shallow water while Pier 4 is on the north side of the slough on land, approximately 16 feet from the water. Typically there are two primary means of installing a large diameter pile; first would be using a vibratory hammer, and secondly the use of a large impact hammer to drive the pile to the final tip elevation. The distances to the various NMFS thresholds were calculated for both an unattenuated pile and assuming a 10 dB reduction with a bubble ring for the attenuated piles. Because the piles at Pier 4 are on land, additional attenuation was not considered for these piles. Table 5 shows the levels used, Table 6 shows the unattenuated distance to the various NMFS criteria and Table 7 shows the attenuated distance to the various NMFS criteria.

[10] Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish, California Department of Transportation, February 2009 and the 2012 Hydroacoustic Compendium

**Table 6 – Computed Distances to NMFS Criteria for Unattenuated 72-inch Steel Shell Pile**

| ***Location*** | ***Distance to 187 dB Cumulative SEL Criteria [A] (feet)*** | ***Distance to 183 dB Cumulative SEL Criteria [A] (feet)*** | ***Distance to 206 dB Peak Criteria (feet)*** | ***Distance to 150 dB RMS Criteria (feet)*** |
|---|---|---|---|---|
| ***East of the Bridge*** | | | | |
| Pier 2 | 2,191[B] | 2,191[B] | 98 | 2,191[B] |
| Pier 4 | 797 | 1,371 | <33 | 1,798[B] |
| ***West of the Bridge*** | | | | |
| Pier 2 | 630[B] | 630[B] | 98 | 630[B] |
| Pier 4 | 979 | 1,371 | <33 | 1,968[2] |

*[A] Single Strike SELs below 150 dB do not accumulate to cause injury to fish*
*[B] Constrained by the river channel*

**Table 7 – Computed Distances to Various NMFS Criteria for Attenuated 72-inch Steel Shell Pile**

| ***Location*** | ***Distance to 187 dB Cumulative SEL Criteria [A]*** | ***Distance to 183 dB Cumulative SEL Criteria [A]*** | ***Distance to 206 dB Peak Criteria*** | ***Distance to 150 dB RMS Criteria*** |
|---|---|---|---|---|
| | ***East of the Bridge*** | | | |
| Pier 2 | 1,371 | 2,191[B] | <33 | 2,191[B] |
| Pier 4 | 797 | 1,371 | <33 | 128 |
| | ***West of the Bridge*** | | | |
| Pier 2 | 630[B] | 630[B] | <33 | 630[B] |
| Pier 4 | 797 | 1,371 | <33 | 1,968[B] |

*[A] Single Strike SELs below 150 dB do not accumulate to cause injury to fish*
*[B] Constrained by the river channel*

<u>24-Inch Steel Shell Piles</u>

Abutments 1 and 5 each have twenty eight 24-inch steel shell piles that will be impact driven in. Abutment 1 is on the south side of Miner Slough in approximately 56 feet from the water and Abutment 5 is on the north side of the slough on land, approximately 85 feet from the water. As with the larger size piles typically there are two means of installing piles; first would be using a vibratory hammer, and secondly the use of an impact hammer to drive the pile to the final tip elevation. Because both abutments are out of the water on land attenuation was not considered for these piles. Table 5 shows the levels used, Table 8 shows the distance to the various NMFs criteria.

**Table 8 – Computed Distances to NMFS Criteria for 24-inch Steel Shell Abutment Piles**

| *Location* | *Distance to 187 dB Cumulative SEL Criteria [A] (feet)* | *Distance to 183 dB Cumulative SEL Criteria [A] (feet)* | *Distance to 206 dB Peak Criteria (feet)* | *Distance to 150 dB RMS Criteria (feet)* |
|---|---|---|---|---|
| | ***East of the Bridge*** | | | |
| Abutment 1 | 46 | 79 | <33 | 111 |
| Abutment 5 | <33 | 46 | <33 | 98 |
| | ***West of the Bridge*** | | | |
| Abutment 1 | 46 | 79 | <33 | <33 |
| Abutment 5 | <33 | 46 | 98 | <33 |

*[A] Single Strike SELs below 150 dB do not accumulate to cause injury to fish*

Pier 3 will be constructed in a coffer dam constructed out of 24-inch sheet piles. Table 9 shows the levels assuming that the piles are driven in a partially de-watered coffer dam. Table 10 shows the distances assuming the coffer dam is totally de-watered or using a bubble ring around the piles being driven. Table 5 shows the levels used for the analysis.

**Table 9 – Computed Distances to NMFS Criteria for Unattenuated 24-inch Steel Shell Piles in Coffer Dam**

| *Location* | *Distance to 187 dB Cumulative SEL Criteria [A] (feet)* | *Distance to 183 dB Cumulative SEL Criteria [A] (feet)* | *Distance to 206 dB Peak Criteria (feet)* | *Distance to 150 dB RMS Criteria (feet)* |
|---|---|---|---|---|
| | ***East of the Bridge*** | | | |
| Pier 3 | 1,457 | 2,000 [B] | <33 | 2,000 [B] |
| | ***West of the Bridge*** | | | |
| Pier 3 | 797 [B] | 797 [B] | <33 | 797 [B] |

*[A] Single Strike SELs below 150 dB do not accumulate to cause injury to fish*
*[B] Constrained by the river channel*

**Table 10 – Computed Distances to NMFS Criteria for Attenuated 24-inch Steel Shell Piles in a Coffer Dam**

| *Location* | *Distance to 187 dB Cumulative SEL Criteria [A] (feet)* | *Distance to 183 dB Cumulative SEL Criteria [A] (feet)* | *Distance to 206 dB Peak Criteria (feet)* | *Distance to 150 dB RMS Criteria (feet)* |
|---|---|---|---|---|
| | ***East of the Bridge*** | | | |
| Pier 3 | 377 | 646 | <33 | 971 |
| | ***West of the Bridge*** | | | |
| Pier 3 | 377 | 646 | <33 | 797[B] |

[A] *Single Strike SELs below 150 dB do not accumulate to cause injury to fish*
[B] *Constrained by the river channel*

<u>Temporary trestle</u>

There will be two trestles on each end of bridge. The one on the south end will be approximately 86-feet long and the other on the north end will be about 204 feet. This will leave an opening of about 85 feet for traffic navigation between the two trestles. Each trestle will be a width of 35 feet to 40 feet with a superstructure of timber decking, steel stringers, and prefab steel bents and a safety railing. The bents will be spaced approximately 25 feet to 40 feet apart. These bents will be supported on piles varying from 15 inches to 36 inches in diameter. These piles have a spacing of 5 feet to 10 feet apart may be driven by an impact hammer or through use of a vibratory hammer. The number of piles is estimated to be approximately 125. Each pile will be approximately 50 feet to 75 feet long.

Based on the information provided, there were four options analyzed for the temporary trestle, all the trestles were assumed to be 40 feet wide. Production was assumed to be one bent per day for all options and all piles were assumed to be 75 feet in length and embedded in the ground 50 feet. The following is a summary of the assumptions used for the rest of the options;

1. Option A – Consists of using 15-inch steel shell piles for the foundation with the bent spacing set at the minimum distance of 25 feet and 10 piles per bent. This would require approximately 12 bents and approximately 120 piles.
2. Option B – Consists of using 24-inch steel shell piles for the foundation with the bent spacing set at the minimum distance of 30 feet and 7 piles per bent. This would require approximately 10 bents and approximately 70 piles.
3. Option C – Consists of using 30-inch steel shell piles for the foundation with the bent spacing set at the minimum distance of 35 feet and 5 piles per bent. This would require approximately 9 bents and approximately 45 piles.
4. Option D – Consists of using 36-inch steel shell piles for the foundation with the bent spacing set at the minimum distance of 40 feet and 4 piles per bent. This would require approximately 8 bents and approximately 32 piles.

Driving of 36-inch shell steel piles in water could generate underwater maximum peak sound pressure levels of about 210 dB at 33 feet from the pile, while 15-inch steel shell piles could generate underwater maximum peak sound pressure levels of about 196 dB at 33 feet from the pile. Sound levels could be much lower in very shallow (i.e., less than 3 feet depth) portions of the slough. Pile driving activities conducted near the slough would generate groundborne vibration that could produce underwater noise. Pile driving activities conducted on land near water bodies have been found to transmit low frequency sound into the water. The mechanisms for transmitting this sound into the water are complex and difficult, if not impossible, to predict. It is anticipated that substantial sounds transmitted into the water from pile driving would only occur in the deeper portions of the river where the water is relatively deep (6 feet or greater). Driving of small steel shell piles on land near the river is likely to result in peak sound pressure levels of less than 200 dB. Table 11 shows the distances to the various NMFS criteria for unattenuated pile installations.

**Table 11 – Computed Distances to NMFS Criteria Unattenuated Pile Driving for Work Structures**

| Structure | Pile Type | Number of piles per day | Distance to 187 dB Cumulative SEL Criteria (feet) | | Distance to 183 dB Cumulative SEL Criteria (feet) | | Distance to 150 dB RMS Criteria (feet) | | Distance to 206 dB Peak Criteria (feet) |
|---|---|---|---|---|---|---|---|---|---|
| | | | West | East | West | East | West | East | Both Directions |
| Option A - Main Work Trestle | 15-inch | 10 | 1,479 | 797[A] | 2,000[A] | 797[A] | 2,000[A] | 797[A] | <33 |
| Option B - Main Work Trestle | 24-inch | 7 | 1,772 | 797[A] | 2,000[A] | 797[A] | 2,000[A] | 797[A] | <33 |
| Option C - Main Work Trestle | 30-inch | 5 | 1,906 | 797[A] | 2,000[A] | 797[A] | 2,000[A] | 797[A] | <33 |
| Option D - Main Work Trestle | 36-inch | 4 | 2,000[A] | 797[A] | 2,000[A] | 797[A] | 2,000[A] | 797[A] | 56 |

[A] *Maximum distance downstream 2,000 feet and upstream 797feet due to curves in river*

The distances to the various NMFS criteria can be reduced by attenuating the noise from the piles by the use of a bubble ring or similar method. Table 12 shows the distances to the various NMFS criteria for attenuated pile installations.

**Table 12 – Computed Distances to NMFS Criteria Attenuated Pile Driving for Work Structures**

| Structure | Pile Type | Number of piles per day | Distance to 187 dB Cumulative SEL Criteria (feet) | | Distance to 183 dB Cumulative SEL Criteria (feet) | | Distance to 150 dB RMS Criteria (feet) | | Distance to 206 dB Peak Criteria (feet) |
|---|---|---|---|---|---|---|---|---|---|
| | | | West | East | West | East | West | East | Both Directions |
| Option A - Main Work Trestle | 15-inch | 10 | 380 | 380 | 656 | 656 | 984 | 797[1] | <33 |
| Option B - Main Work Trestle | 24-inch | 7 | 456 | 456 | 787 | 787 | 1,667 | 797[1] | <33 |
| Option C - Main Work Trestle | 30-inch | 5 | 492 | 492 | 846 | 797[1] | 1,909 | 797[1] | <33 |
| Option D - Main Work Trestle | 36-inch | 4 | 646 | 646 | 1,112 | 797[1] | 2,000[1] | 797[1] | <33 |

[1] *Maximum distance downstream 2,000 feet and upstream 797 feet due to curves in river*

### Attenuation Methods

Air bubble curtains, either confined or un-confined, have been shown to reduce sound pressure levels for pile driving in water by up to about 10-20 dB within 984 feet of the pile. The amount of attenuation may be less, especially at distant locations from the pile, because of the contribution of sound propagating through the bottom substrate. At the Benicia-Martinez Bridge and San Francisco-Oakland Bay Bridge projects, at least 10 dB of sound reduction was obtained using bubble curtains. In some cases, up to 30 dB of attenuation was obtained. At the Humboldt Bay Seismic Retrofit Project, reductions of between 12 and 16 dB were achieved using either an unconfined bubble ring or a bubble ring in an isolation casing, with the best results being the unconfined bubble ring.

The design of the specific bubble ring configuration will depend on several factors, such as the depth of water and the water current, and must be designed individually for each project and location within the project. Air bubble curtain systems are used during production pile driving to reduce underwater sound pressures. Typically, a system consists of stacked rings to generate air bubbles throughout the entire water column surrounding the piles, even with currents. A bubble curtain system is generally composed of air compressor(s), supply lines to deliver the air, distribution manifolds or headers, perforated aeration pipes, and a frame. The frame is used to facilitate transportation and placement of the system, keep the aeration pipes stable, and provide ballast to counteract the buoyancy of the aeration pipes during pile-driving operations. Bubble curtain designs consist of single or multiple concentric layers of perforated aeration pipes (stacked vertically). Pipes in any layer are arranged in a geometric pattern, which will allow the pile-driving operation to be completely enclosed by bubbles for the full depth of the water column. The lowest layer of perforated aeration pipe is designed to ensure contact with the mud line without sinking into the bottom substrates. A proper combination of bubble density and close proximity of bubbles to the pile would be most effective. Numerous smaller bubbles are more effective, since they displace more water between the bubbles. This pattern would have to be maintained throughout the water column.

Experimental results show that an encapsulated gas bubble curtain can provide substantial noise reduction ranging up to 40 dB, depending on frequency. Typically this technology focuses on reducing sound over a set frequency band rather than a broad band approach. The system would likely be designed to reduce sounds over the frequency range that pile driving produces the highest sounds. This system uses a curtain of encapsulated bubbles to shield either a noise source or a receiver. The only data available on the effectiveness of this system was gathered at a water treatment plant construction project in Lake Travis, Texas. This project was used as a source-of-opportunity in an experiment where a distant receiving area was shielded from incoming impulse sounds generated by the pile driving events. The pile driving was approximately 1.55 miles from the receiving area. The piles being driven were composed of 48-inch diameter steel pipe. The average measured peak-to peak sound pressure level generated by the pile driving events was 185 dB re 1μPa at a distance of 112m from the pile. The average sound pressure level at the receiving area 1.55 miles away was 150 dB re 1μPa, prior to treatment by the bubble screen. The peak pressures were observed in the 100 Hz – 300 Hz frequency range. The data was acquired over multiple hammer strikes on eight different piles.[11] The broadband reduction in sound level was not reported. The area where this project was undertaken was in a lake not a river environment with moving water. Because of this it is not reasonable to predict how effective the encapsulated bubble curtain would be in a shallow river environment due to a lack of demonstrated data from a similar environment. Based on this it was determined that the conservative approach would be to assume a 10 dB reduction, similar to a traditional bubble curtain system.

[11] Kevin M. Lee, Mark S. Wochner and Preston S. Wilson. UW132. Mitigation of low-frequency underwater anthropogenic noise using stationary encapsulated gas bubbles. Acoustical Society of America [DOI: 10.1121/1.4767960], Received 21 Sep 2012; published 2 Nov 2012, Proceedings of Meetings on Acoustics, Vol. 17, 070011 (2012)

# Attachment A
# Pile Driving Calculation

## Unattenuated New Bridge Construction

| New Bridge Structure | Station | Pile Type | Pile Length | Number of Piles | Pile Location | Piles per Day | Estimated Blows per pile (assumes piles driven to 90% of length ) | Distance to water (feet) | Peak | RMS | Single Strike SEL[1] | Cumulative SEL @ 33 feet |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Abutment 1 | M1 26+19.93 | 24-inch | 65 | 28 | On Land | 7 | 1,170 | 56 | 179 | 159 | 150 | 189 |
| Pier 2 | M1 26+79.14 | 72-inch | 100 | 2 | In Water | 2 | 1,620 | 0 | 214 | 199 | 189 | 224 |
| Pier 3 | M1 27+89.14 | 24-inch | 100 | 25 | In Coffer Dam | 10 | 1,800 | 0 | 200 | 185 | 172 | 215 |
| Pier 4 | M1 28+99.14 | 72-inch | 100 | 2 | On Land | 2 | 1,620 | 16 | 204 | 185 | 175 | 210 |
| Abutment 5 | M1 29+61.90 | 24-inch | 65 | 28 | On Land | 7 | 1,170 | 85 | 172 | 158 | 146 | 185 |

[1] *- Single Strike SELs below 150 do not accumulate to cause injury to fish.*

| New Bridge Structure | East of the Bridge (Upstream) | | | | West of the Bridge (Downstream) | | | |
|---|---|---|---|---|---|---|---|---|
| | Distance to 187 dB Cumulative SEL Criteria (feet) | Distance to 183 dB Cumulative SEL Criteria (feet) | Distance to 150 dB RMS criteria (feet) | Distance to 206 dB Peak criteria (feet) | Distance to 187 dB Cumulative SEL Criteria (feet) | Distance to 183 dB Cumulative SEL Criteria (feet) | Distance to 150 dB RMS criteria (feet) | Distance to 206 dB Peak criteria (feet) |
| Abutment 1 | 43 | 75 | 112 | <33 | 43 | 75 | 112 | <33 |
| Pier 2 | 2,192[2] | 2,192[2] | 2,192[2] | 98 | 630[2] | 630[2] | 630[2] | 98 |
| Pier 3 | 1,371 | 2,000[2] | 2000[2] | <33 | 797[2] | 797[2] | 797[2] | <33 |
| Pier 4 | 751 | 1,290 | 1,798[2] | <33 | 750 | 1,290 | 1,968[2] | <33 |
| Abutment 5 | <33 | 43 | 98 | <33 | <33 | 43 | 98 | <33 |

[2] *Constrained by the river channel*

## Attenuated New Bridge Construction

| New Bridge Structure | Station | Pile Type | Pile Length | Number of Piles | Pile Location | Piles per Day | Estimated Blows per pile (assumes piles driven to 90% of length ) | Distance to water (feet) | Peak | RMS | Single Strike SEL[1] | Cumulative SEL @ 10m |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Abutment 1 | M1 26+19.93 | 24-inch | 65 | 28 | On Land | 7 | 1,170 | 56 | ***Piles on land and cannot be attenuated*** | | | |
| Pier 2 | M1 26+79.14 | 72-inch | 100 | 2 | In Water | 2 | 1,620 | 0 | 204 | 189 | 179 | 214 |
| Pier 3 | M1 27+89.14 | 24-inch | 100 | 25 | In Coffer Dam | 10 | 1,800 | 0 | 190 | 175 | 162 | 205 |
| Pier 4 | M1 28+99.14 | 72-inch | 100 | 2 | On Land | 2 | 1,620 | 16 | ***Piles on land and cannot be attenuated*** | | | |
| Abutment 5 | M1 29+61.90 | 24-inch | 65 | 28 | On Land | 7 | 1,170 | 85 | ***Piles on land and cannot be attenuated*** | | | |

[1] *- Single Strike SELs below 150 do not accumulate to cause injury to fish.*

| New Bridge Structure | East of the Bridge (Upstream) | | | | West of the Bridge (Downstream) | | | |
|---|---|---|---|---|---|---|---|---|
| | Distance to 187 dB Cumulative SEL Criteria (feet) | Distance to 183 dB Cumulative SEL Criteria (feet) | Distance to 150 dB RMS criteria (feet) | Distance to 206 dB Peak criteria (feet) | Distance to 187 dB Cumulative SEL Criteria (feet) | Distance to 183 dB Cumulative SEL Criteria (feet) | Distance to 150 dB RMS criteria (feet) | Distance to 206 dB Peak criteria (feet) |
| Abutment 1 | ***Piles on land and cannot be attenuated*** | | | | | | | |
| Pier 2 | 1,290 | 2,192[2] | 2,192[2] | <33 | 630[2] | 630[2] | 630[2] | <33 |
| Pier 3 | 354 | 607 | 971 | <33 | 354 | 607 | 797[2] | <33 |
| Pier 4 | ***Piles on land and cannot be attenuated*** | | | | | | | |
| Abutment 5 | ***Piles on land and cannot be attenuated*** | | | | | | | |

[2] *Constrained by the river channel*

**Source Levels Used in analysis of new Bridge**

| ***New Bridge*** | Station | Pile | Distance to water | | Water Depth | Peak | RMS | SEL | Commnets |
|---|---|---|---|---|---|---|---|---|---|
| | | | Feet | Meters | | | | | |
| Abutement 1 | M1 26+19.93 | 2 ft. Steel Shell | 56 | 17 | On Land | 179 | 159 | 150 | Willits Bypass |
| Pier 2 | M1 26+79.14 | 6 ft. Steel Shell | 0 | 0 | 4 feet | 214 | 195 | 185 | Feather River Bridge |
| Pier 3 | M1 27+89.14 | 2 ft. Steel Shell | 0 | 0 | 10 feet | 200 | 185 | 172 | Dewatered coffer dam |
| | | Sheet Piles | | | | 205 | 189 | 179 | Parson Slough |
| Pier 4 | M1 28+99.14 | 6 ft. Steel Shell | 16 | 5 | On Land | 204 | Not Reported | 175 | Feather River Bridge 72" Land Based Piles 12 meters from Edge of water (measured at 16 |
| Abutement 5 | M1 29+61.90 | 2 ft. Steel Shell | 85 | 26 | On Land | 172 | 158 | 146 | Willits Bypass |

**Vibratory Levels used in Sheet Pile Analysis**

| New Bridge | Station | Pile Type | Distance to Water | | Water Depth | Peak | RMS | SEL | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | | | Feet | Meters | | | | | |
| Pier 3 | M1 27+89.14 | 24-inch Sheet Pile | 0 | 0 | 10 feet | *177* | *163* | *162* | *Berth 23, Port of Oakland* |

*The levels used in analysis were reduced 2 dB due to the difference in water depth the sheet piles at Berth 23 were in 12-14 meter deep water vs the water depth at Minor Slough of approximately 3 meters deep.*

## Unattenuated Work Trestle

| | Station | Pile Type | Driven Pile Length | Number Of Piles | Impact Drive | Blows Assumes 20 blows fer foot | Estimated Blows Per Pile | Piles per Day | Peak | RMS | Single Strike SEL | Distance Measured | Transmission Loss | Cumulative SEL @ 33 ft. | Distance to 187 dB Cumulative SEL Critera (feet) | Distance to 183 dB Cumulative SEL Critera (feet) | Distance to 150 dB RMS Critera (feet) | Distance to 187 dB Cumulative SEL Critera (feet) | Distance to 183 dB Cumulative SEL Critera (feet) | Distance to 150 dB RMS Critera (feet) | Distance to 206 dB Peak Critera (feet) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| For the assessment - all piles were considered to be in the water and production was considered one bent per day. | | 15-inch Steel Shell | 50 | 120 | 6,000 | 120,000 | 1000 | 10 | 196 | 180 | 170 | 20 | 17 | 210 | 1,479 | 2000 [1] | 2000 [1] | 797 [1] | 797 [1] | 797 [1] | <33 |
| | | 24-inch. Steel Shell | 50 | 70 | 3,500 | 70,000 | 1000 | 7 | 203 | 189 | 178 | 10 | 17 | 216 | 1,772 | 2000 [1] | 2000 [1] | 797 [1] | 797 [1] | 797 [1] | <33 |
| | | 30-inch. Steel Shell | 50 | 45 | 2,250 | 45,000 | 1000 | 5 | 205 | 190 | 180 | 10 | 17 | 217 | 1,906 | 2000 [1] | 2000 [1] | 797 [1] | 797 [1] | 797 [1] | <33 |
| | | 36-inch. Steel Shell | 50 | 32 | 1,600 | 32,000 | 1000 | 4 | 210 | 193 | 183 | 10 | 17 | 219 | 2000 [1] | 2000 [1] | 2000 [1] | 797 [1] | 797 [1] | 797 [1] | 56 |

[1] Constrained by river channel

## Attenuated Work Trestle

| | Station | Pile Type | Driven Pile Length | Number Of Piles | Impact Drive | Blows | Estimated Blows Per Pile | Piles per Day | Peak | RMS | Single Strike SEL | Distance Measured | Transmission Loss | Cumulative SEL @ 33 ft. | Distance to 187 dB Cumulative SEL Critera (feet) | Distance to 183 dB Cumulative SEL Critera (feet) | Distance to 150 dB RMS Critera (feet) | Distance to 187 dB Cumulative SEL Critera (feet) | Distance to 183 dB Cumulative SEL Critera (feet) | Distance to 150 dB RMS Critera (feet) | Distance to 206 dB Peak Critera (feet) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| For the assessment - all piles were considered to be in the water and production was considered one bent per day. | | 15-inch Steel Shell | 50 | 120 | 6,000 | 120,000 | 1000 | 10 | 186 | 170 | 160 | 20 | 17 | 200 | 382 | 656 | 985 | 382 | 656 | 797 [1] | <33 |
| | | 24-inch. Steel Shell | 50 | 70 | 3,500 | 70,000 | 1000 | 7 | 193 | 179 | 168 | 10 | 17 | 206 | 457 | 786 | 1,667 | 457 | 786 | 797 [1] | <33 |
| | | 30-inch. Steel Shell | 50 | 45 | 2,250 | 45,000 | 1000 | 5 | 195 | 180 | 170 | 10 | 17 | 207 | 492 | 846 | 1,908 | 492 | 797 [1] | 797 [1] | <33 |
| | | 36-inch. Steel Shell | 50 | 32 | 1,600 | 32,000 | 1000 | 4 | 200 | 183 | 173 | 10 | 17 | 209 | 648 | 1113 | 2000 [1] | 797 [1] | 797 [1] | 797 [1] | <33 |

[1] Constrained by river channel

## Source Levels Used in analysis of Temporary Trestle

| DATA used | Job | Distance | Peak | RMS | SEL |
|---|---|---|---|---|---|
| 14-inch | Richmond San- | 66 feet | 196 | 180 | 170 |

| | | | | | |
|---|---|---|---|---|---|
| | Rafael | | | | |
| 24-inch | Rodeo Dock | 33 feet | 203 | 189 | 178 |
| 30-inch | Richmond San-Rafael | 33 feet | 205 | 190 | -- |
| 36-inch | Humboldt Bay | 33 feet | 210 | 193 | 183 |

# Attachment B


**Figure 1 - Pier 2 Un-Attenuated 187 and 183 dB Cumulative SEL**

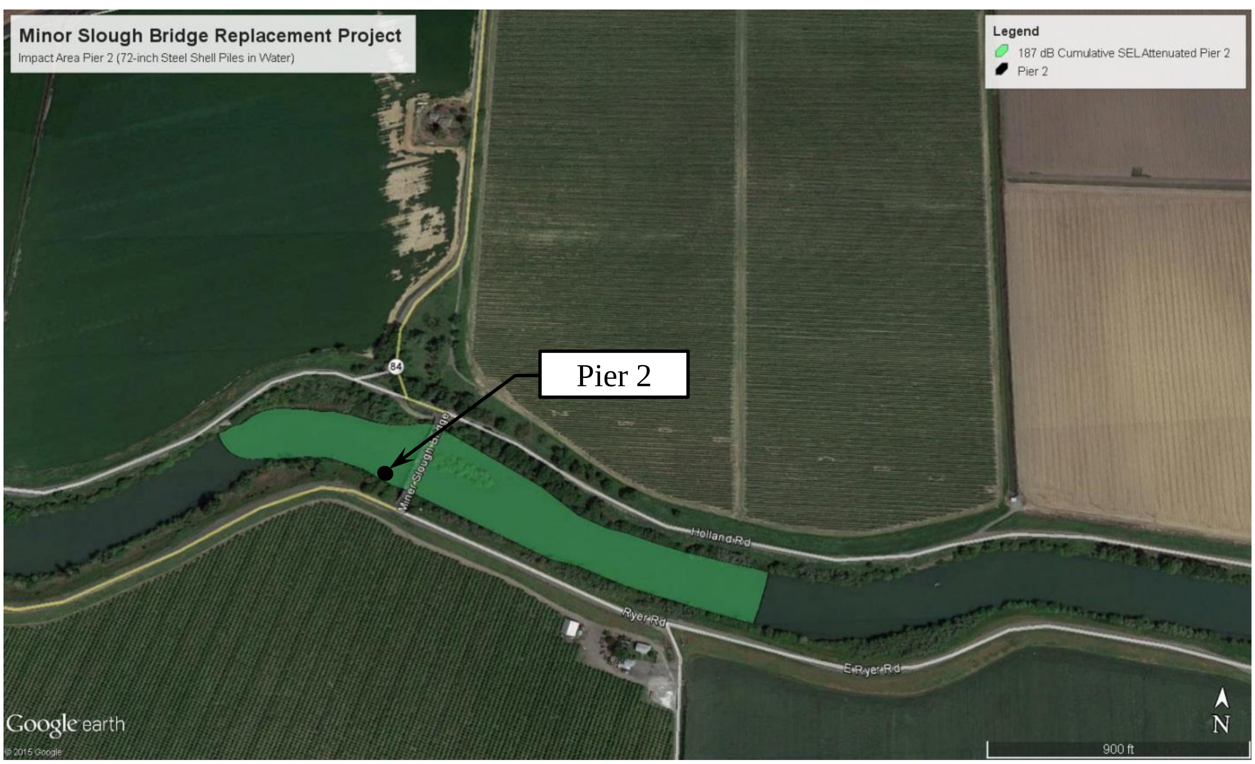


**Figure 2 - Pier 2 Attenuated 187 dB Cumulative SEL**

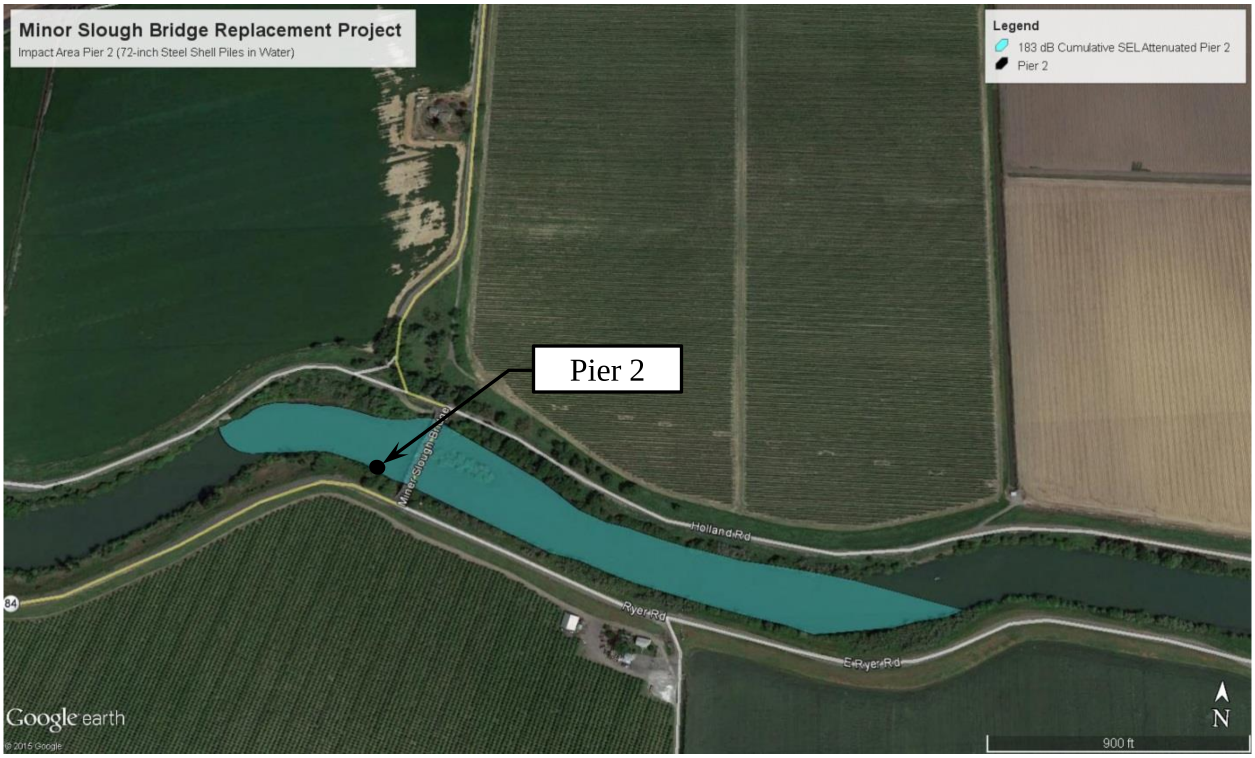


**Figure 3 - Pier 2 Attenuated 183 dB Cumulative SEL**

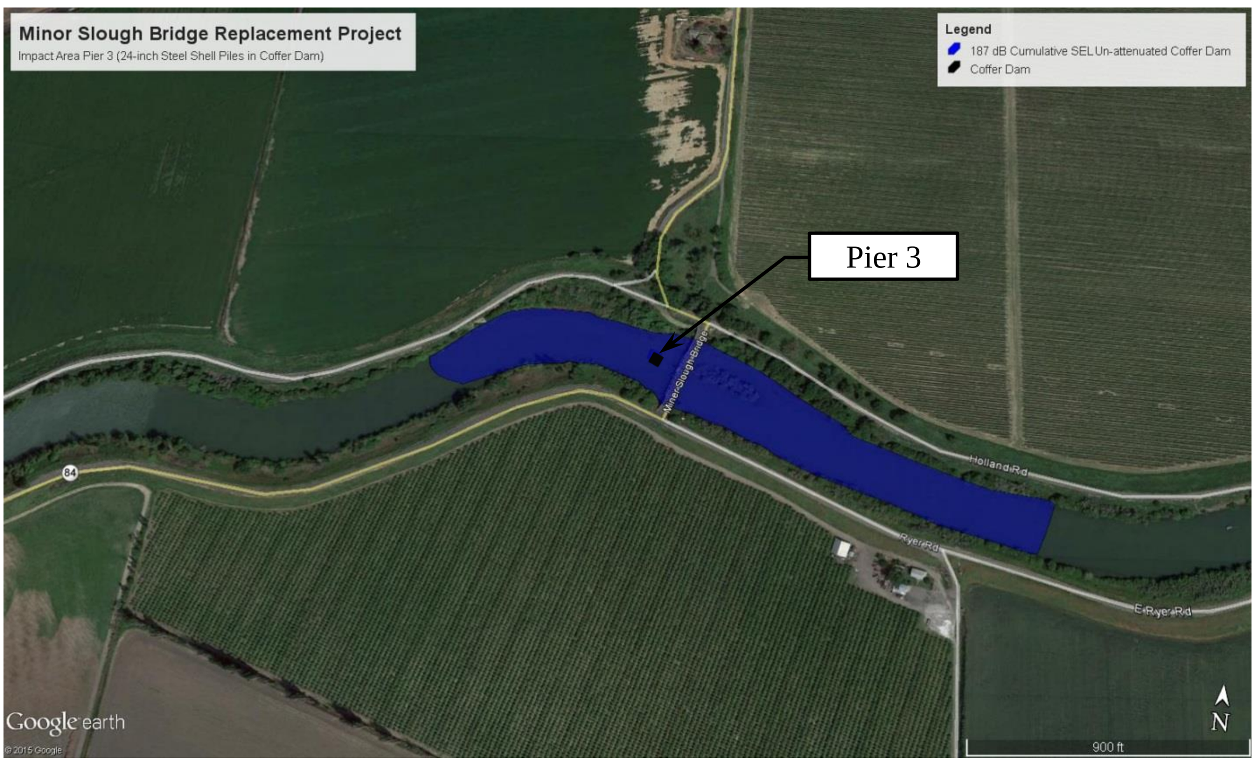


**Figure 4 - Pier 3 Un-Attenuated 187 dB Cumulative SEL**

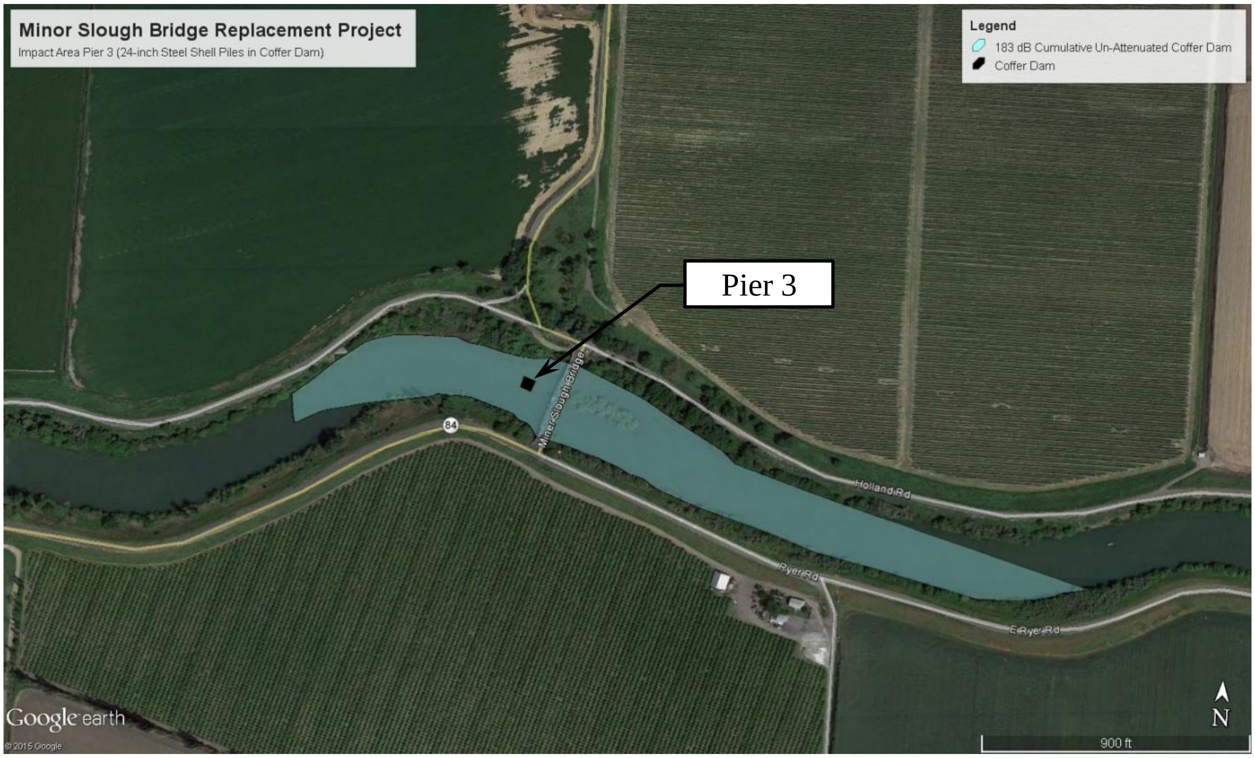


**Figure 5 - Pier 3 Un-Attenuated 183 dB Cumulative SEL**

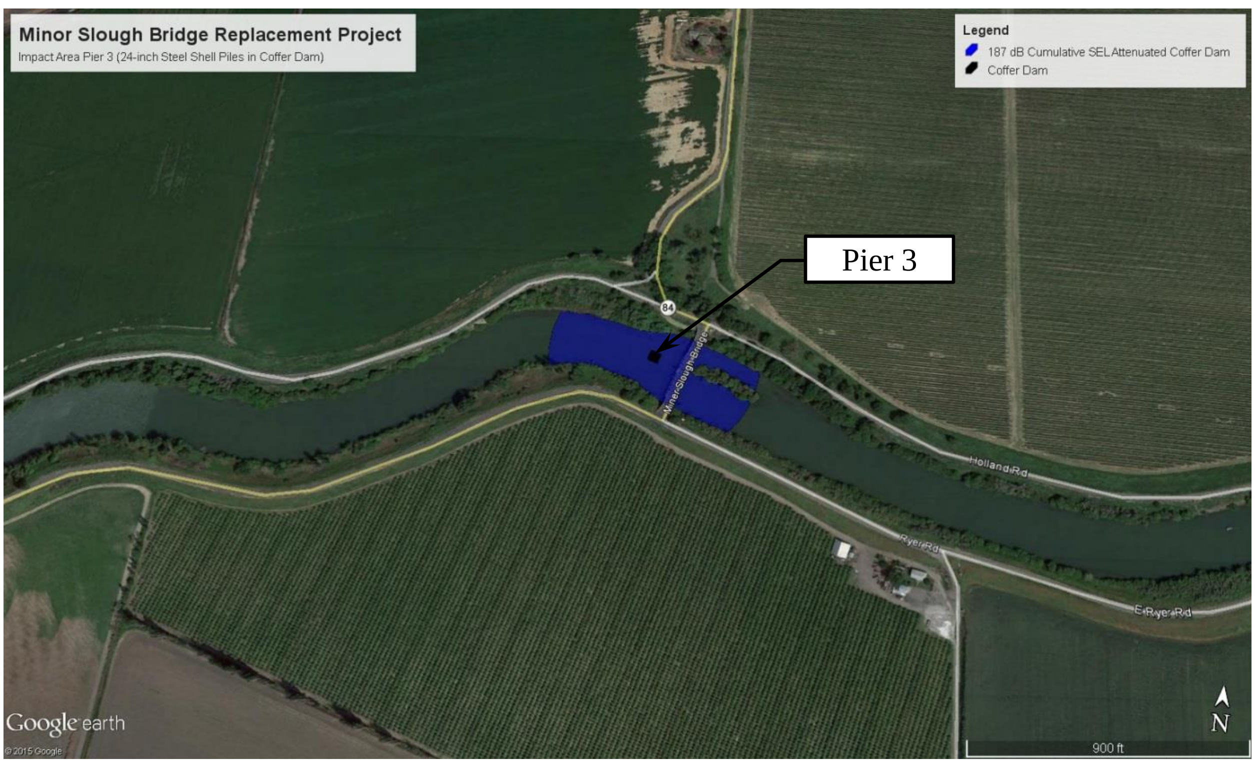


**Figure 6 - Pier 3 Attenuated 187 dB Cumulative SEL**

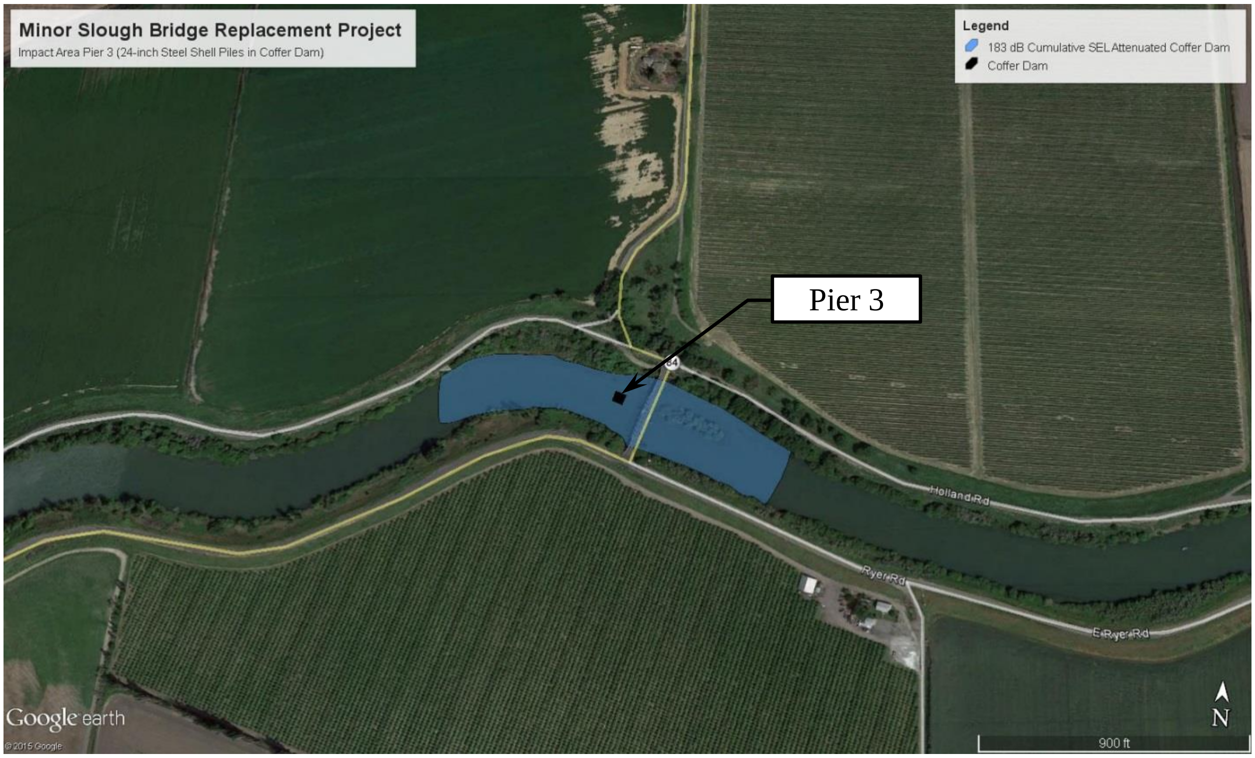


**Figure 7 - Pier 3 Attenuated 183 dB Cumulative SEL**

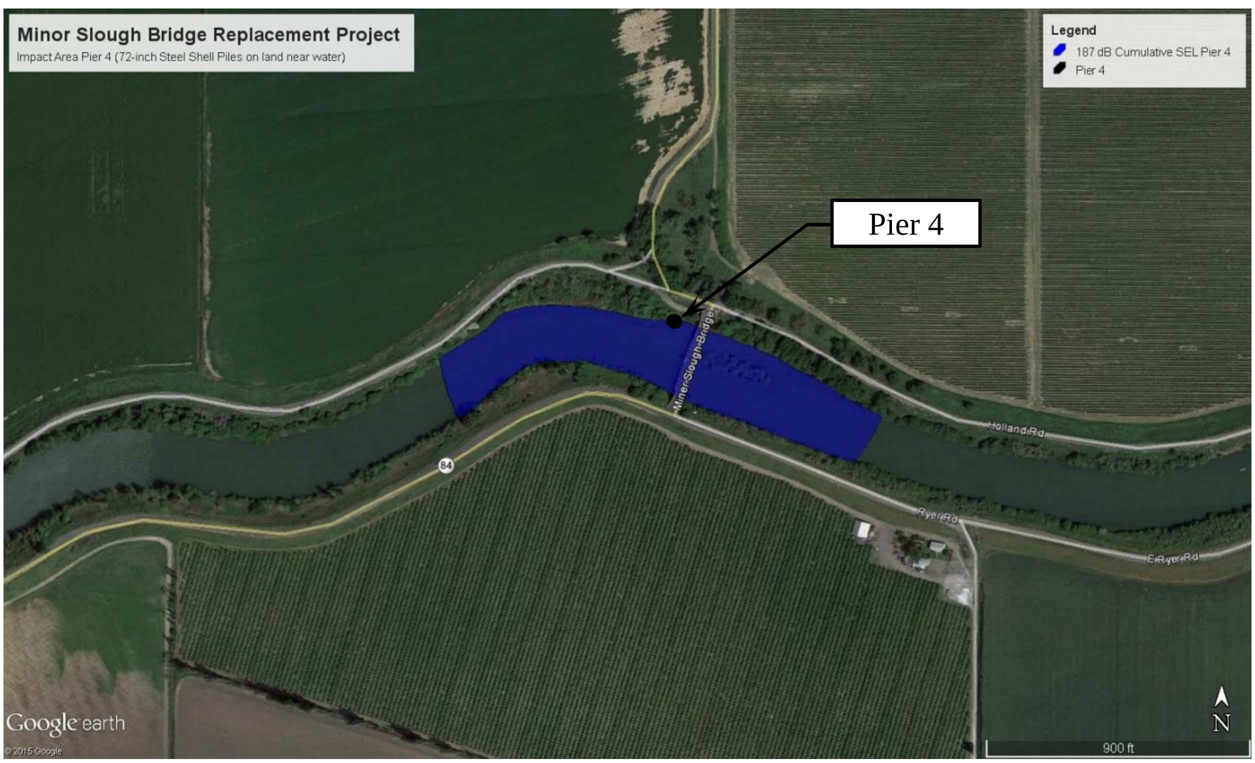


**Figure 8 - Pier 4(on Land) 187 dB Cumulative SEL**

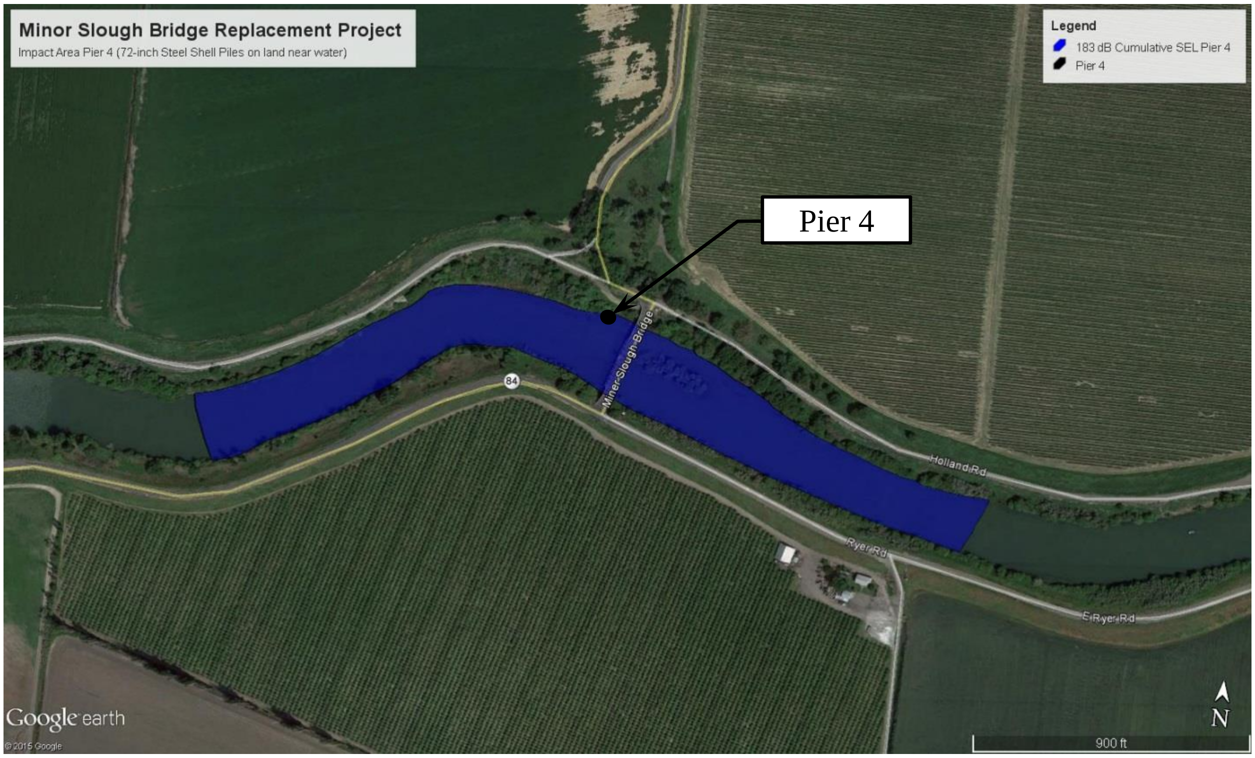


**Figure 9 - Pier 4(on Land) 183 dB Cumulative SEL**